Canada - Geodetic Survey

DEPARTMENT OF THE INTERIOR, CANADA

HON. THOMAS G. MURPHY, Minister H. H. ROWATT, Deputy Minister

GEODETIC SURVEY OF CANADA

NOEL J. OGILVIE, Director

ANNUAL REPORT

OF THE DIRECTOR

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDED MARCH 31, 1930

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1931

GEODETIC SURVEY OPERATIONS

Top—Geodetic Survey Building at Ottawa.

Second row, left to right—
North end of Standards building, showing five-meter bar apparatus.
Office of Precise Level Adjusting Division.
Fiducial point at south end of 50-meter comparator, in Standards building.

Third row, left to right—
Precise Level, U.S.C. & G.S. Pattern.
Latest Model Primary Triangulation theodolite.
Latest Model Astronomical Transit.
Electric Signal Lamp for Primary Triangulation.
Precise Level, Zeiss Model.

Bottom row, left to right—
Observing on Secondary Triangulation.
Photographic and Transport Hydroplane, Canadian model.
Sending instructions to light keepers by heliograph.
Setting rear end of tape in Base line measurement.
Observing Precise Levels in the Yukon Territory.
A Transport Hydroplane at rest.
Observing Primary Triangulation.

On flanks—
Triangulation Tower near Chatham, Ont., with Lamp-stand extended 37 feet. Height of Lamp-stand. 147 feet.

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THE GEODETIC SURVEY OF CANADA

ANNUAL REPORT OF THE DIRECTOR, NOEL J. OGILVIE

INTRODUCTION

The operations of the Geodetic Survey of Canada, Department of the Interior, both in the field and in the office, during the fiscal year ended March 31, 1930, showed satisfactory progress.

Field parties carried out successfully the operations undertaken in British Columbia, Saskatchewan, Ontario, Quebec, and New Brunswick.

The following table shows the field work accomplished in 1929-30 and the total to date:—

Operations	1929		Total to Date	
	Axial length miles	Area square miles	Axial length miles	Area square miles
Completed primary triangulation	628	12,857	6,783	187,332
Completed secondary triangulation	99	1,345	973	5,605
Reconnaissance	538	13,723	.....	
Precise traverse	13	.....	422	
Precise levelling	451	.....	24,274	
Secondary levelling	425	.....	10,258	
	Number		Number	
Standard precise bench marks	224	.....	8,419	
Standard secondary bench marks	162	.....	3,328	
Fundamental bench marks	19	.....	86	
Astronomical stations	14	.....	46	
Laplace stations	3	.....	49	
Base lines	2	.....	28	

In response to requests from federal and provincial government offices, municipalities, corporations and the engineering public, this Survey has promptly furnished geodetic data for geographic positions and for elevations above sea-level. The results of certain refinements in latitudes and longitudes and in elevations above sea-level have been prepared for publication and others are in course of preparation.

The material for the contribution of the Geodetic Survey of Canada to the Fourth General Conference of the International Geodetic and Geophysical Union, at Stockholm, Sweden, has been prepared.

Progress is reported in the development of special methods for the accurate control of geodetic work in Canada, where, on account of the great lengths of the geodetic figures encountered, special means of control have to be devised.

As an economical substitute for triangulation through level terrains where standing timber would obstruct the line of sight between station towers, precise traverse has been used as in former years. In such cases investigation has been made as to the conformation of the traverse to the curvature of the earth's surface.

New field instruments have been tested and valuable data as to the most advantageous type for use in Canada have been recorded. The precise determination of the longitude of points in portions of Canada which have no telegraph lines, is frequently of importance to the Geodetic Survey. Wireless time signals have again been used with advantage in such cases.

On account of its economy, aeroplane transportation of engineers and survey equipment and supplies has become a feature of the field operations of the Geodetic Survey of Canada. This service is provided through co-operation with the Royal Canadian Air Force.

Seven publications of the Geodetic Survey of Canada were printed and distributed. The mailing list for publications is revised annually.

TRIANGULATION AND TRAVERSE

During the field season of 1929 steady progress was recorded on various parts of the primary triangulation net of Canada as well as on two secondary triangulation nets of restricted areas. The progress of the triangulation during the season was not as great as that of the previous year, owing largely to atmospheric conditions which rendered it exceedingly difficult to secure the required accuracy of angular measurements. A comparison of the results of the two seasons is given in the following table:—

Triangulation and Traverse

—	1928		1929	
	Axial length miles	Area square miles	Axial length miles	Area square miles
Completed primary triangulation	751	14,175	628	12,857
Completed secondary triangulation	.....	.....	99	1,345
Reconnaissance	875	19,860	538	13,723
Precise traverse	29	.....	13	

Use of Aeroplanes in Geodetic Operations

A feature of the 1929 season of the Geodetic Survey was the extension of the use of aeroplanes in geodetic operations. Through the co-operation of this Survey and the Royal Canadian Air Force, the requisite number of planes and pilots were provided for this work. During the season about 300 hours were flown on transportation of astronomical parties to points difficult of access, general reconnaissance flights for the selection of the best triangulation routes, detailed reconnaissance flights and transportation of station-preparation and angular-measurement parties.

In one area in western Quebec all of the triangulation operations were carried on with aeroplanes as the sole medium of transport, thus introducing a new departure in geodetic practice. The reconnaissance, or selection of triangulation stations in this area, was carried out experimentally by plane during the winter of 1928-29—see the Annual Report of the Director for the fiscal year ending March 31, 1929—and during the season of 1929 the experiment was successfully extended to the transportation of station-preparation parties and angular-measurement parties.

The district in which this operation was carried on is one devoid of roads but abounding in lakes on which pontoon-equipped planes can land, and the distance between a triangulation station and the nearest landing was usually

not greater than three miles. Ordinary transport there is by canoe with numerous portages around rapids, a method which is circuitous, slow and very difficult for an operation such as triangulation where close co-ordination of a number of parties is an essential. Air transport is therefore admirably adapted to this country and by this means a marked saving of time and money has been effected, as the transportation is performed by aeroplanes engaged on photographic operations at intervals when the weather is unsuitable for photography.

The operations in 1928 and 1929 have shown that geodetic reconnaissance, both general and detailed, can be successfully made by aeroplane, and that an area thus covered in a few hours would take weeks or months of arduous travel by other methods. The stations having been selected, the tower-building party can be transported by air and landed at a point on some lake near the station at which the first tower is required. The work completed, the party is moved to its next station by the plane which brings in, on its trip, fresh supplies and materials. The observing party sets out its lights and moves from station to station by organizing similar trips. In addition to these advantages the chief of the party and the head office in Ottawa are able to keep in almost daily touch with the various widely scattered units of the organization.

Primary Triangulation in Southern British Columbia

Triangulation operations in British Columbia during 1929 were a continuation of a triangulation and traverse net in the interior of the province. The western and northern sides of this loop, lying along the coast from Vancouver to Prince Rupert and along the Canadian National railway from Prince Rupert to Prince George, respectively, are completed. Work on the southern and eastern sides of this loop, from Vancouver to Prince George via the Fraser River watershed, was begun in 1929 at the Vancouver end. This part of the loop will not be completed until 1931.

Details of the 1929 operations follow:—

Results Obtained.—Reconnaissance: 2 new stations selected. *Station Preparation:* 13 stations prepared for observing; distance covered, 180 miles. *Angular measurements:* 7 stations completed; axial length of net, 100 miles; area covered, 2,800 square miles.

In the lower Fraser River valley, where the 1929 operations took place, observing conditions even in normal seasons are unfavourable due to rain and fog in the wet period and to smoke from cities, land clearing and bush fires in dry weather. In 1929 these conditions were accentuated by a record rainfall during the month of June accompanied by the usual clouds covering the mountain tops. This period was followed by one of warm dry weather which brought on a large number of forest fires, so that the air was filled with smoke during most of August and September. The result was a retarded progress record for angular measurements for the season.

The reconnaissance for this section was done by aeroplane by Mr. H. F. Lambart in 1921. The stations were marked and prepared for observing at the same time, but subsequently the trails had become overgrown and had to be cleared out again. New observing tripods were necessary. An investigation of the ground in the vicinity of Stations Barr and Fan was made, with a view to widening the triangulation at this point, but the country was found to be too rugged and difficult of access to make this practicable.

This net is joined to the coast triangulation near Vancouver, where observing was started from the three established stations, Garner, Bruce and Constitution. In the early part of the season angular measurements were made by one observing party only, but during the last month two parties were employed.


GEODETIC SURVEY OF CANADA
Noel J. Ogilvie, Director
TRIANGULATION
Dec. 31st. 1929
Statute Miles
100 0 100 200 300 400 500

Royal Canadian Air Force aeroplanes from Jericho Beach Air station were frequently employed for transportation between the coast stations, and thereby much valuable time was saved, as the customary means of travel is by boat.

Early in September a reconnaissance trip was made by aeroplane north from Prince George towards the headwaters of Finlay river with a view to the future extension of the triangulation in that locality. Another flight was made over the Rocky mountains by the Pine River pass to Moberly lake and Hudson Hope, returning by the Peace River pass, over Finlay to Summit lake. These trips were made in two flights with Royal Canadian Air Force planes of the photographic detachment employed on the survey of the Pacific Great Eastern Railway land grant. The topography of the country lends itself admirably to triangulation, and the main problem will be that of tranportation. There is a well established water route from Summit lake along the middle of the valley which would take care of the main transportation. Side trips could be made by plane, utilizing the numerous lakes for landing places, or, by pack horses.

Primary Triangulation in Saskatchewan

In 1929 triangulation operations in the Prairie Provinces were confined to the province of Saskatchewan and were a development of the control system planned for mid-western Canada.

It may be worth while at this time to indicate in general the nature of the plans for triangulation in these provinces and in the Northwest Territories, thereby explaining the necessity for the operations of the Geodetic Survey during the last few years in a country already well supplied with a control basis of development in the accurate Dominion Lands Survey system.

The subdivision surveys in Alberta extend 450 miles and in Saskatchewan 350 miles north of the international boundary. North of this subdivided area is a district well over 1,000 miles square, the development of which is proceeding very fast. This district is largely devoid of control except for scattered astronomical stations. To be of assistance in the orderly development of this northern district the Geodetic Survey for several years has been operating in the southern parts of the Prairie Provinces laying the foundation from which triangulation can be readily pushed northward when required.

In addition to this consideration the triangulation programs on the prairies and in British Columbia are being proceeded with simultaneously along plans made long in advance of actual operations, the nets east and west of the Rocky mountains being planned as a unit, each dependent for its accuracy to a certain extent on the other. For these reasons it was believed advisable to establish a strong east-and-west control net across the Prairie Provinces as far north as easy transportation would permit. This net extends from Edmonton to Prince Albert and, in consideration of its north-and-south connections to the international boundary and its east-and-west extensions, three or four years will be required in its completion.

The 1929 operations consisted in the completion of that part of the above east-and-west net extending between Lloydminster and Prince Albert, together with the reconnaissance, or selection of stations, for nets southward from Prince Albert to the international boundary, and some distance northward and eastward from Prince Albert.

Results Obtained.—Reconnaissance: 48 primary and 2 supplementary stations selected; axial length of nets, 350 miles; area covered, 7,700 square miles. *Station Preparation:* 37 standard piers and 14 towers built; distance covered, 175 miles. *Angular Measurements:* 26 primary and 2 supplementary stations completed; axial length of net, 180 miles; area covered, 2,700 square miles; connections made with 9 land survey corners.

In the development of the plan for fundamental control of Western Canada and for supplying local demands for geodetic data the triangulation net across the northern part of the Prairie Provinces was extended eastward from Prince Albert as far as Crooked river where a station was selected close to the right of way of the Canadian National railway. The object of this connection is to facilitate the establishment of geodetic control in the vicinity of the mining developments around The Pas by means of a precise traverse along this railway, the terrain here being unsuitable for economic triangulation. A projection of this traverse would supply, at least temporarily, the needs of the Churchill district.

From the main net at Prince Albert stations were selected for the control of the Prince Albert National Park. This net runs to a point about 65 miles north of Prince Albert to the vicinity of lake Waskesiu. Reconnaissance was discontinued at this point because it became necessary to adopt some means of transportation other than the automobile, and if aeroplane transport should prove advisable it would become necessary to inspect the country to the north before deciding on a route and an objective. A plane and pilot became available through co-operation with the Royal Canadian Air Force and a flight was made, near the end of the season, northward from Prince Albert with very satisfactory results in that all information necessary to the intelligent consideration of all alternative routes was obtained.

In what might be called the fundamental control or main scheme, stations were selected for a net from the triangulation in the vicinity of Rosthern southward to the triangulation along the international boundary. Geodetic control for the cities of Saskatoon, Moose Jaw and Regina is provided for in this scheme.

Work on preparation of stations progressed very satisfactorily.

Continuous difficulty was encountered during the season in maintaining the required standard of accuracy in the angular measurements. Various changes were made in the field procedure without locating the trouble, and exhaustive tests at the close of the season gave equally barren results, except to apparently eliminate everything but continuously unfavourable atmospheric conditions as the likely cause of the trouble.

These difficulties delayed the progress of the angular measurements considerably, as many stations had to be re-occupied to discover errors made at the time the first angular measurements were taken. The number of stations completed in 1929 was only 26 primary and 2 supplementary as compared with 53 primary and 11 supplementary in 1928, yet sufficient observations were made in 1929 to have completed 100 stations under favourable conditions. This may be shown in another way by taking account of the number of times the various stations were occupied.

Times Occupied	No. of Stations	Total Occupations
1	2	2
2	7	14
3	5	15
4	5	20
5	3	15
6	4	24
10	1	10
		100

Thus almost 93 per cent of the stations required more than one occupation in order to secure accurate angular measurements. Every effort will be made in 1930 to discover any controllable source of error which may have caused this trouble.

Primary Triangulation and Precise Traverse in Northern Ontario

The work of the parties in northern Ontario was carried on in two sections of country: triangulation in the district from North Bay to Sudbury, and precise traverse northerly from Cochrane along the James Bay extension of the Temiskaming and Northern Ontario railway.

Results Obtained.—Triangulation. Reconnaissance: 20 primary and 18 secondary stations selected, axial length, 100 miles; area covered, 4,230 square miles. *Station Preparation:* 17 stations prepared, at 8 of which towers were built. *Angular Measurements:* 12 primary and 3 secondary stations completed; axial length of net, 71 miles; area covered, 1,077 square miles.

Precise Traverse.—Reconnaissance: 27 stations selected over a distance of 61 miles. *Station Preparation:* 19 stations prepared at 7 of which towers were built. *Angular Measurements:* 19 main traverse stations completed over a distance of 28 miles. *Traverse Measured:* 13 miles.

The reconnaissance was started twenty miles east of Sudbury and was carried through the Sudbury mining area, with stations placed one figure north and northwest of the main scheme to allow for future expansion in either one of these directions without any re-occupation of stations.

On the southern side of the Sudbury area a connection was made with the stations previously selected in a proposed net across Georgian bay, which will eventually form a large closed loop with the main net in southern Ontario. A number of secondary stations were also selected in the area surrounding Sudbury, as the importance of this area justified more complete control than the sections further east.

The angular measurement was started at North Bay and continued westerly to Sudbury. The first section of the work had stations on both sides of lake Nipissing. Motor transport was used entirely for the stations north of the lake, as roads reached within two or three miles of the stations. Those on the south of the lake were reached by either canoe or motor boat. West of lake Nipissing the stations, with two exceptions, were all within an hour's walk of roads on which the motor trucks could be used.

The country around lake Nipissing is rather low with very few outstanding hills and at nearly every station a tower had to be built. In the area around Sudbury the hills are higher and, as the tops of most of them are bare rock, fewer towers were necessary.

In the latter part of the season the parties, with the exception of the reconnaissance engineer and his assistant, were engaged on precise traverse north of Cochrane. The station preparation party moved there on August 18, and the angular measurement party on September 1. On account of the nature of the ground, which is mostly muskeg with a few hard clay knolls, the cost of station preparation for this traverse was quite heavy.

The stations on the traverse could not be marked as permanently as the stations on triangulation, as many of the points where main azimuth stations had to be placed were in very soft, deep muskeg, where a small movement of the station mark would be sufficient to affect the azimuth of a short line. The bases of the marks in such places were consequently set at a considerable depth in the ground to provide stability.

Primary Triangulation in Quebec

The 1929 primary triangulation operations in western Quebec come under five headings: checking by ground methods of the reconnaissance, carried out by aeroplane in the winter of 1928-29, of two nets 190 miles in length between Senneterre and La Tuque; aeroplane reconnaissance on a net 100 miles in length northward from Oskelaneo towards lake Chibougamau; station preparation and

angular measurements eastward from Senneterre; station preparation and angular measurements northward from Ottawa along the Gatineau valley; and secondary triangulation around Chicoutimi.

Ground Checking of Aeroplane Reconnaissance.—On page 15 of the Annual Report of the Director of the Geodetic Survey for the fiscal year ended March 31, 1929, a report was made of the method of selection of triangulation stations from an aeroplane in an area between Senneterre and La Tuque. Twenty-two primary and four supplementary stations were selected in ten days, 17 flying hours, whereas, due to the inaccessibility of the area, this operation would have taken two seasons had ground methods been employed.

This reconnaissance was checked over by ground methods in 1929, the operation being greatly simplified and expedited by the knowledge of the country obtained from the air. The success of the aeroplane reconnaissance was established; of the 26 stations selected from the air only one had to be abandoned on account of one blocked line, the cost of both the aeroplane reconnaissance and the subsequent ground checking was less than the cost of the ground reconnaissance alone would have been and one season was saved in the completion of the triangulation.

While only one blocked line was found in the aeroplane reconnaissance, a number of lines were found to be open which had been believed to be closed as a result of the plane reconnaissance, a circumstance which permitted a simplification of the net. In addition the plotting of a number of the stations on the only available maps revealed appreciable map-errors, a condition which could not be checked from the air since no bearings of lines could be taken. These errors caused some difficulty in the station preparation and setting of lights for the angular measurements, but this trouble should be avoidable as greater experience is gained in aeroplane reconnaissance. As a result of this experience it is believed that by the use of stereoscopic, oblique photography it will be possible to determine in nearly all cases whether or not the selected stations are intervisible.

Aeroplane Reconnaissance.—Anticipating the completion in 1930 or 1931 of the triangulation at present laid out along the Canadian National railway between Senneterre and La Tuque and the net northward from Ottawa to connect with this net following the Gatineau valley, an aeroplane reconnaissance for a net northward from the Canadian National railway at Oskelaneo was commenced in February, 1930. This reconnaissance was completed for a distance of 100 miles north of the railway and consisted of 14 stations covering an area of 1,625 square miles.

Gatineau Valley Net.—The program laid out in this area consisted in the preparation and occupation for the measurement of horizontal and vertical angles of the stations of a net tending northerly from a point north of Ottawa in the Gatineau River valley.

Results Obtained.—Station Preparation: 18 stations prepared at 14 of which tripods were built inside steel fire lookout towers. *Angular Measurements:* 16 primary and 6 secondary stations completed; axial length of nets, primary 105 miles, secondary 100 miles; area covered, primary 2,500 square miles, secondary 1,350 miles.

Reconnaissance engineers of the Geodetic Survey co-operating with the fire protection staff of the Canadian International Paper Company had previously selected a large number of points in the area suitable for both triangulation and fire lookout stations, and on these points a primary scheme of triangulation of an average width of 22 miles was developed straddling the Gatineau River valley. Along the west side of the primary net a secondary scheme was laid out extending its width by an average of 13 miles.

A large proportion of the points selected had been prepared by the company as fire protection lookout stations, which involved the clearing of timber to open roads and trails to the sites, the erection of 80-foot steel towers, and the installation of a telephone system. All this work proved of inestimable value to both the station preparation party and the observing party of the Survey.

In June 10 a station-preparation party moved from New Brunswick and commenced preparing the necessary stations in advance of the observing party. In all, 18 stations were prepared by this party in four months; this included the construction of 18 concrete monuments and the erection of 14 wooden tripods ranging from 25 to 60 feet in height, in addition to the cutting and blazing of several trails. The advantage of the work done by the Canadian International Paper Company was clearly reflected in the progress made. The party in this area was able to carry on with a minimum amount of equipment and, having the advantage of the steel towers, it was necessary to construct a tripod and platform only. During the season no delays were occasioned by inability of the station-preparation party to keep in advance of the observers.

During the months of June and July the progress of the angular-measurement party was retarded due to a number of causes, chiefly smoky and hazy weather and the inexperience of the lightkeepers. From the first of August, however, weather conditions for observing improved and observing progressed as rapidly as could be expected, considering the accessibility of the stations. Before the break-up on October 12 the program which had been originally set for the party was completed. Observations were completed as far as the Poigan-Lyon line. (See page 14 of the Annual Report of the Director of the Geodetic Survey of Canada for 1928-29).

In all 16 primary and 6 secondary stations were observed with a total of 79 primary and 72 secondary directions. Reciprocal zenith distances at 21 stations and non-reciprocal zenith distances on 10 other points were obtained. Control for the vertical work was carried to the primary network from three Geodetic Survey bench marks. In addition to the above, 4 stations were prepared by the observing party, and one blocked line was cleared, which entailed about a week's work for the whole party cutting a line through a heavily wooded hardwood ridge.

All horizontal and vertical angles of the primary points were observed with the new $5\frac{1}{2}$-inch theodolite, and those at the secondary stations with the $3\frac{3}{4}$-inch theodolite. These instruments have been found ideal for the work and results of the observations made with them have been found to be well within the recognized standard of accuracy set by this Survey.

The area covered by the work of the past season is approximately 3,500 square miles, having a total length of nearly 100 miles, with an average width of 35 miles. The average length of line observed was 20 miles, and the average closing error of the triangles involved in the primary scheme amounts to 0·6 of a second with a maximum triangular closure of 2·4 seconds.

A preliminary adjustment of the work shows an average correction to the observed directions of only 0·36 of a second.

Senneterre-East Section.—This operation consisted in the remeasurement of the angles of a portion of the 1928 triangulation west of Senneterre, P.Q., together with the extension of this net south and east of Senneterre.

It had been expected that this work would be joined to that net running north up the Gatineau River valley, thus completing a loop in western Quebec some 750 miles in circumference, bounded on the south and west by a net along the Ottawa river, on the north by that along the Canadian National railway and on the east by the Gatineau River net. This expectation was not fully realized.

Results Obtained.—Station Preparation: 12 stations prepared, at 6 of which towers were built and at 5 of which tripods were built inside fire lookout towers. *Angular Measurement:* 18 primary and 3 supplementary stations completed; axial length of the net, 118 miles; area covered, 2,450 square miles.

In the country covered by this operation canoe routes offered the only means of transportation; it is a very difficult country in which to secure the close co-ordination of all parties which is essential to primary triangulation. At the same time numerous lakes are found here, which made it an ideal area for the operation of pontoon-equipped aircraft. Advantage was therefore taken of the presence at Senneterre of a photographic detachment of the Royal Canadian Air Force to try the experiment of transportation of all triangulation parties on days unsuitable for aerial photography. The experiment was a complete success.

Considerable difficulty was experienced during the season in securing the required accuracy of angular measurements, due to unusually adverse atmospheric conditions which caused horizontal refraction in lines of sight.

Chicoutimi.—At the request of the Chicoutimi Harbour Commission the area covered by the operations of this body on the Saguenay river was triangulated and fifteen stations established with results better than those of secondray accuracy. The $3\frac{3}{4}$-inch theodolite was used on this work with satisfactory results.

Primary Triangulation in New Brunswick

Results Obtained.—Angular Measurements: 7 stations completed; axial length of net, 48 miles; area covered, 1,300 square miles.

This operation was the completion of a net along the west side of the province, and was a continuation of the 1928 work. With the finish of this net early in the season all of the primary triangulation required for some time in the Maritime Provinces is completed, and any further operations in these areas will be confined to secondary triangulation or to traverse.

In the triangulation of this net heights of stations were derived by trigonometric levelling and more reliable elevations than had been available to date were secured for a number of hills in the interior of the province. These points with their elevations above mean sea-level are as follows:—

	Geodetic Survey Altitude Feet
Sugar Loaf, just south of the town of Campbellton, N.B.	929
Squaw Cap, near the junction of the Upsalquitch with the Restigouche river	1,584
Five Finger fire tower, monument at base	1,413
Mt. Carleton, at the headwaters of the Tobique and Nipisiguit rivers	2,690
Quisibis, about 15-20 miles east of Edmundston, N.B.	1,619
Bald Peak, near Riley Brook on the Tobique road	2,086
Costigan, on south branch Gulquac river, 10 miles east of Oxbow on the Tobique River road.	2,197
Blue Bell, 4 miles north of Blue Bell station on C.N. Ry., Victoria County	1,754
Black, 5 miles west of Summit station on C.N. Ry., near the boundary between Victoria and Carleton Counties	1,705
Otter Slide, 4 miles north of Napadogan station on C.N. Ry., York County	1,622
Mars Hill, one mile west of International Boundary, in State of Maine	1,746

Big Bald mountain, on the lower south branch of the Nipisiguit river, was stated by earlier investigators to be as high as or higher than mount Carleton. A later value of its elevation is given in White's "Altitudes in Canada" as 2,500

feet. The Geodetic Survey has not obtained an elevation for this hill, but has determined instrumentally that its elevation is lower than that of mount Carleton.

GEODETIC ASTRONOMY AND ISOSTASY

Geodetic Astronomy

The field work in geodetic astronomy during the field season of 1929 consisted in making Laplace determinations at certain stations in the Northern Ontario-Quebec triangulation net, in observing the longitude and latitude at geodetic stations in Gaspé peninsula and on the shores of Chaleur bay, and in observing the longitude and latitude at points on the west shore of Hudson bay and on the Manitoba-Ontario boundary line.

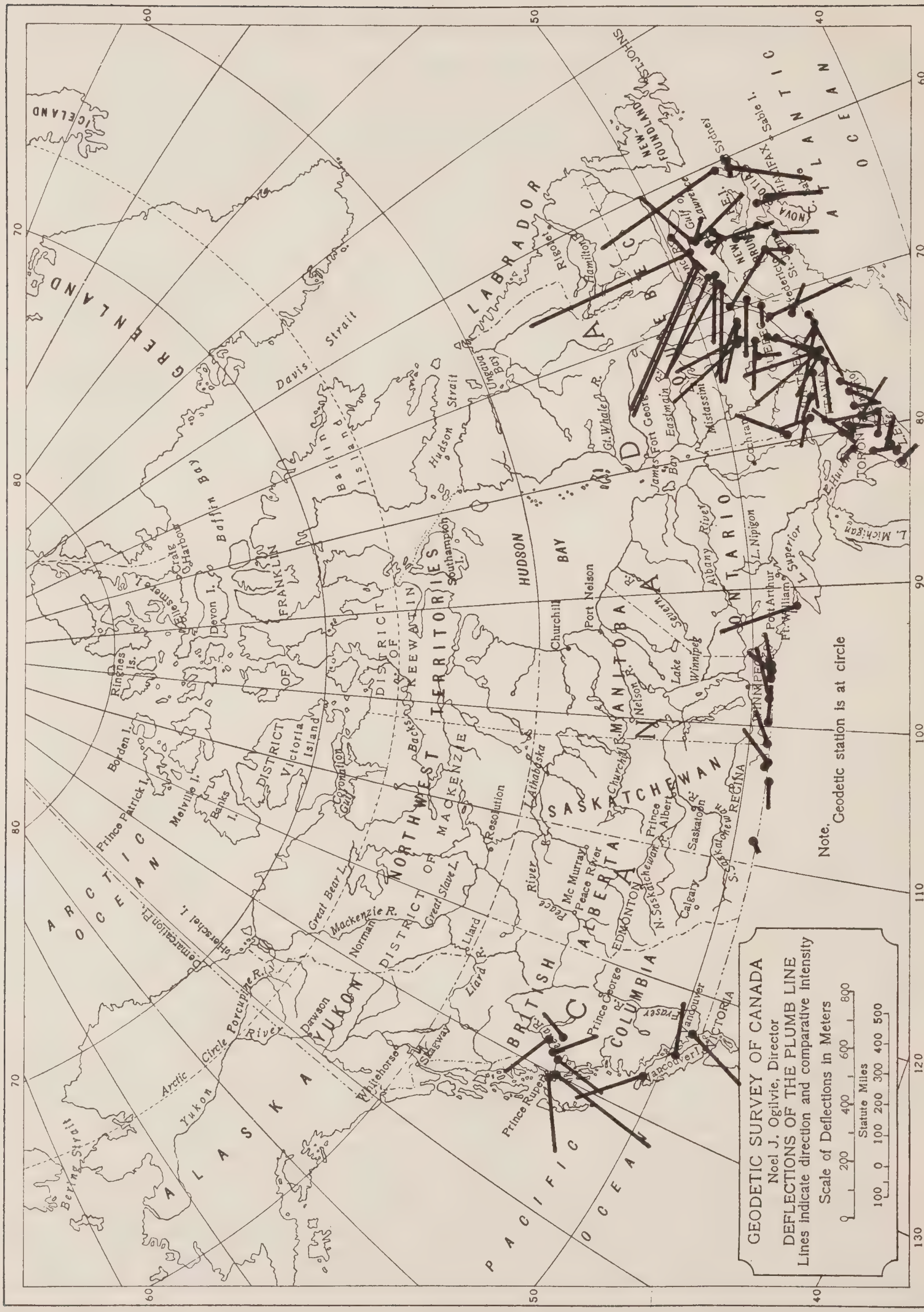
The stations in the Northern Ontario-Quebec net, occupied for Laplace determinations were Calvert near Porquis Junction, Ont.; Makamik near Makamik, P.Q.; and West Base near Senneterre, P.Q. Longitude, latitude and azimuth were determined at these three stations, the azimuth being measured on the lines Calvert to Walker, Makamik to Destor, and West Base to Montgay. These three Laplace determinations will furnish control for first order triangulation in this area.

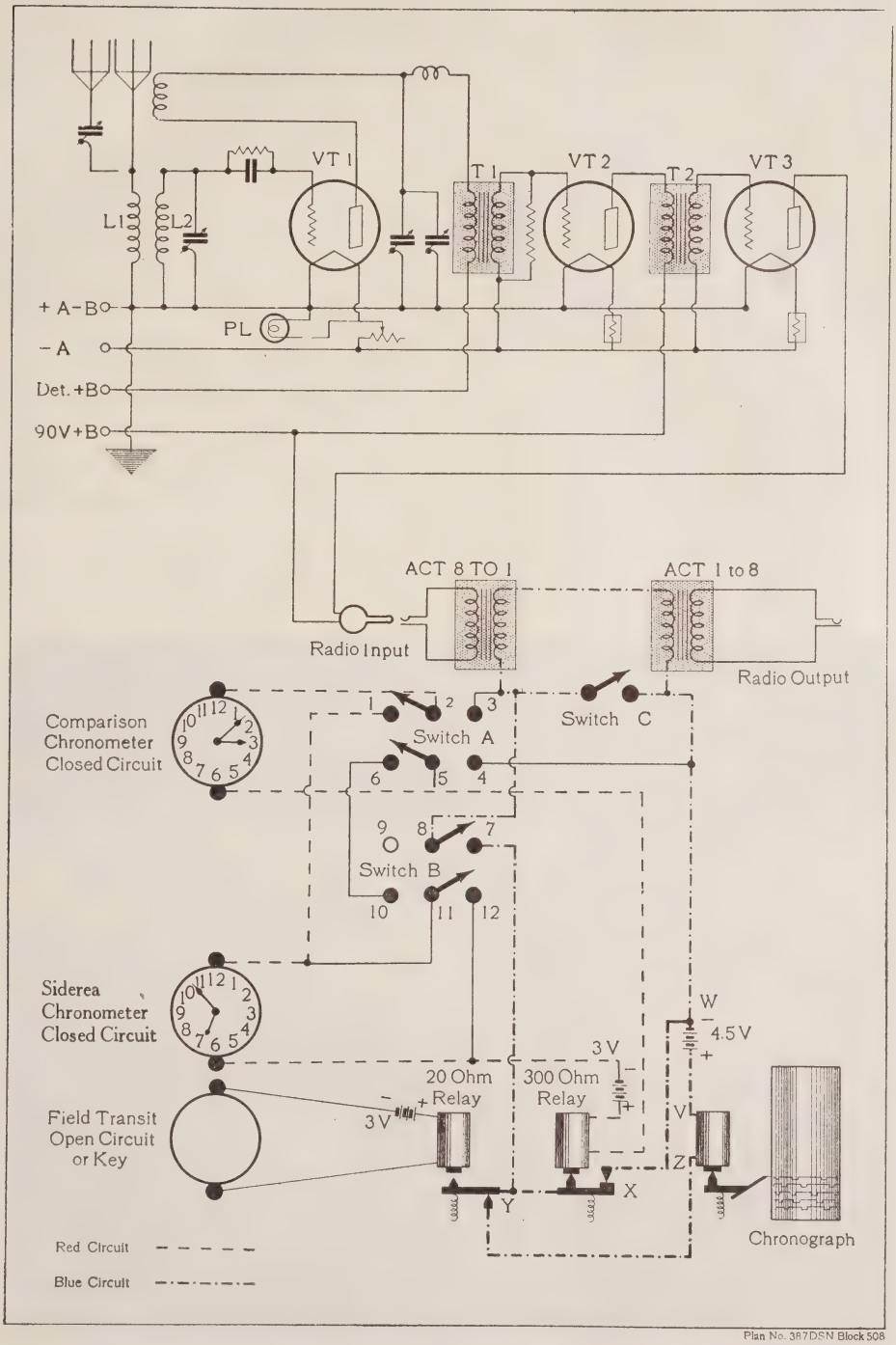
The geodetic stations observed for longitude and latitude in Gaspé peninsula and on the shores of Chaleur bay were Mont Joli, Cap des Rosiers, Rivière la Madeleine, Percé, Chandler, Paspebiac, Barbeau, Grand Anse, and Miscou. These observations were made in connection with the determination of the deflection of the plumb line in Canada. On the accompanying map are plotted the deflections of the plumb line at certain geodetic triangulation points in all the provinces of the Dominion except one. An examination of the stations situated around Gaspé peninsula will show deflections producing errors in the geographical positions determined astronomically amounting to two thousand feet or more.

In connection with the survey of the Manitoba-Ontario boundary line, a longitude and latitude station was established at the east end of Island lake. Aeroplane service from Norway House on lake Winnipeg furnished the transportation of this party. The trip from Norway House to Island lake, by the canoe route, could not have been made in less than six weeks, whereas by plane it was made each way in a few hours. When the observations at Island lake were completed, the party was brought back to Norway House where the reductions of the observations were all made and the final result of the longitude and latitude determined. As this value of the Island lake longitude and latitude was necessary to the enginer engaged in the laying down of the boundary from the Twelfth Base Line to Island lake, the aeroplane was again utilized to carry the information from Norway House to the boundary engineer.

From Norway House to The Pas the outfit was again transported by aeroplane, while the rest of the journey to Churchill was made by rail. Four astronomical stations were established on the west shore of Hudson bay. The transportation was furnished by two nineteen-foot freight canoes. An outboard motor was fitted to one of them and it towed the other.

The stations determined on Hudson bay were 60th parallel, Hubbard Point, Churchill, and Cape Churchill. The station on the 60th parallel, the boundary line between the western provinces and the Northwest Territories is at the point where that parallel meets the west shore of Hudson bay. This station is marked by a concrete post, over which a large cairn of stones was built. The other three stations were marked by concrete posts, which were tied to the nearest hydrographic signals. These four stations are being used by the Hydrographic Survey, Department of Marine, in the charting of Hudson bay.


GEODETIC SURVEY OF CANADA
Noel J. Ogilvie, Director
DEFLECTIONS OF THE PLUMB LINE
Lines indicate direction and comparative intensity
Scale of Deflections in Meters
100 0 200 400 600 800
Statute Miles
100 0 100 200 300 400 500
Note. Geodetic station is at circle
HUDSON BAY
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
ALASKA
GREENLAND
LABRADOR
ONTARIO
MANITOBA
SASKATCHEWAN
ALBERTA
BRITISH COLUMBIA
YUKON
NORTHWEST TERRITORIES



Longitude Operations. Wiring of Field Station apparatus for Time Signals.

The diagram on page 19 shows the switch-board arrangement used in primary longitude determination for recording star observations and making clock comparisons with the incoming radio time signals.

During star observations both " A " and " B " switches are in the left hand position which allows the sidereal clock to record with the transit on the chronograph. Switch " C " may be open or closed. To record a comparison of the sidereal and comparison clocks, switch " B " is opened.

To compare the comparison clock with the incoming radio signals, switch " B " is placed in the right hand position and switch " C " opened. In this position the comparison clock interrupts the radio circuit through the 300-ohm relay causing the radio to function only for the latter half of each second. Since this clock is rated to gain one second in every 50 in mean time, a vernier effect is created and coincidences are obtained and recorded every 50 seconds. Inductance from the relay sometimes causes a banging noise in the ear phones which may be eliminated by changing switch " A " over to the right hand position thus interrupting the radio circuit through the comparison clock itself, the relay battery being cut off. The switch " C " may be closed at any time to stop the interruptions and bring in continuous radio reception.

The sidereal and comparison clocks are in series in the *red cricuit*. When either opens the circuit, their common relay (300 ohm) opens, as the current from the 3-volt battery is cut off. This opens the *heavy blue circuit* which actuates the chronograph and registers the signals.

Before and after the field season observations for personal equation were made by the three observers engaged in the astronomical field work.

Longitude Instruments. This outfit has given results of the high order of accuracy required by the Geodetic Survey of Canada and at the same time is light enough for transportation by canoe, back pack or aeroplane.


GEODETIC SURVEY OF CANADA
Noel J. Ogilvie, Director
OBSERVED ASTRONOMICAL POINTS.
Dec. 31st. 1929
Statute Miles
100 0 100 200 300 400 500

All the field parties are equipped with the broken-telescope type of transit and with wireless receiving sets. These transits are especially suitable for field work in localities where transportation is difficult. They can be easily carried by pack train, canoe, aeroplane or back pack.

Base Lines

Two base lines, one in the Province of Alberta near Kitscoty and the other in the Province of Saskatchewan near Kinistino, measured in 1929, will provide control for the scale of the geodetic triangulation in Alberta and Saskatchewan.

Standards

The fifty-metre invar tapes used both in base line measurement and in precise traverse were standardized before and after their use in the field. The nickel bar No. 10239 is always used as the standard of length in determining the lengths of these invar tapes.

Isostasy

In connection with the study of isostasy a considerable amount of progress has been made during the year. Field observations as outlined on page 17 have been made in Gaspé peninsula. Templates have been prepared for the scaling of topographical maps and the material will be ready for publication in the near future.

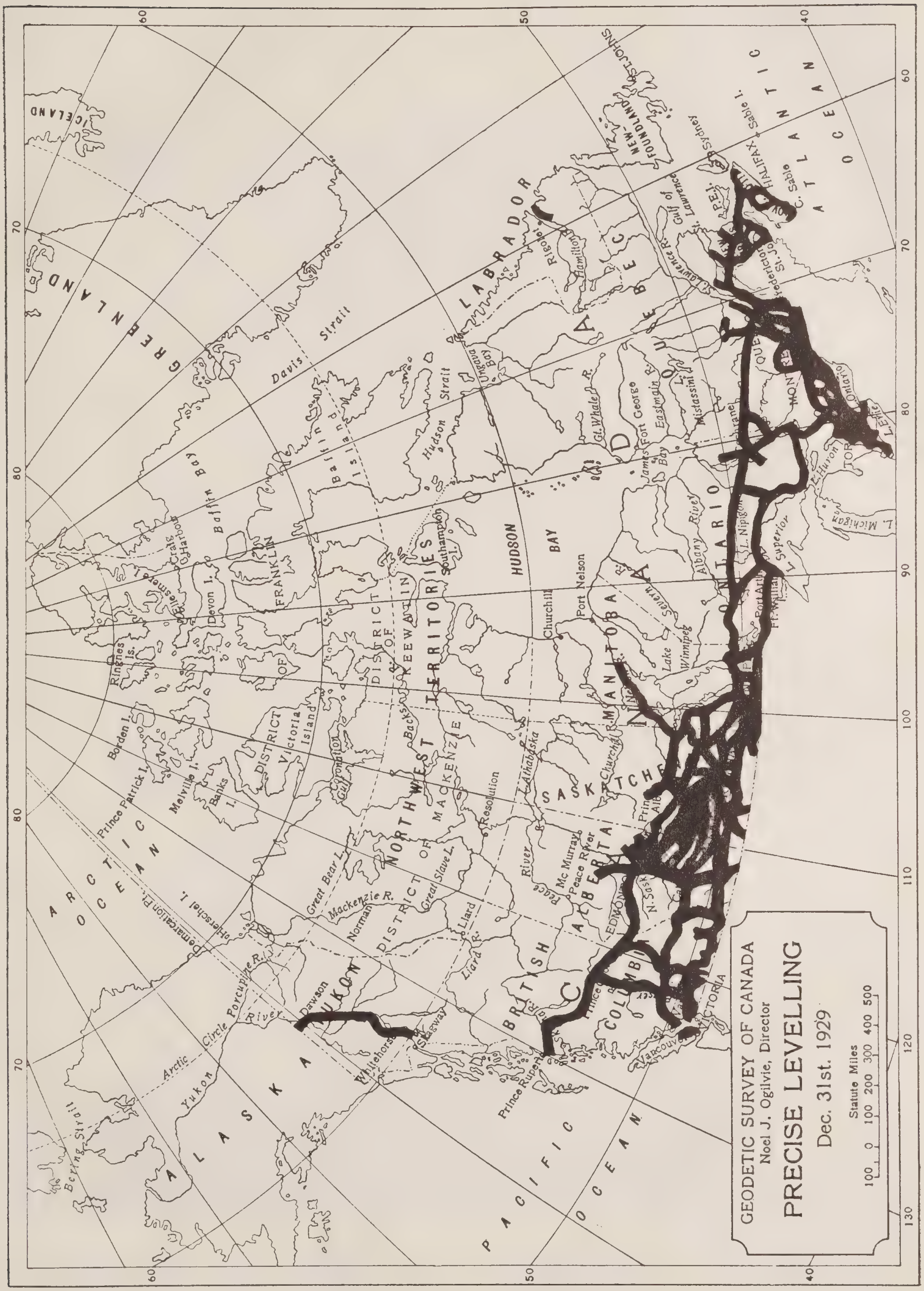
LEVELLING

Office Operations

The publication of information regarding precise level bench marks was continued and during the year six pamphlets dealing with such bench marks were issued. These completed a series of precise levelling publications, nine in number. The first, No. 16, includes bench marks in the Maritime Provinces. Two publications have been issued for the province of Quebec, one for the area south of St. Lawrence river, and one for that to the north. There are also two for Ontario, the dividing line running through Parry Sound. Levelling in each of the remaining provinces is given in a separate publication, the last in the series being No. 24, which gives the precise bench marks in British Columbia.

The nine publications include 8,128 bench marks, and for these the detailed descriptions and the elevations are given. They occur along 23,813 miles of precise levelling. Each bench mark is listed under the name of the nearest railway station, and the stations are arranged in alphabetical order for each province. There are, on an average, 76 pages in a publication and levelling results for 480 railway stations. The largest of the series is that which deals with southern Ontario, and contains 92 pages with 595 stations. In the whole series there are 4,300 stations, in the vicinity of each of which one precise level bench mark at least has been established. This number is about 60 per cent of all the railway stations in the Dominion.

Profiles of all railway lines constructed in Canada during the year have been obtained, with very few exceptions. The elevations recorded along such lines are listed and the elevations are co-ordinated to the datum of mean sea-level. Ninety-three rolls of profiles covering 1,630 miles were received during the year. There are now in stock 669 rolls, including 14,284 miles of railways. Of this total mileage elevations have been listed and co-ordinated along 10,150 miles. These lists are typed in convenient form for reference, and copies are


GEODETIC SURVEY OF CANADA
Noel J. Ogilvie, Director
PRECISE LEVELLING
Dec. 31st. 1929
Statute Miles

now available for the use of surveyors and engineers who may need elevations in particular areas. Many of the railway lines run through districts where few other elevations have been recorded.

There has been a considerable amount of work in connection with the bench marks placed along secondary lines of levelling in the Prairie Provinces. About 4,000 permanent bench marks (iron pipes 4 feet long with a 7-inch foot-plate, and usually filled with concrete) have been established in the southerly parts of these provinces. These levels, which run along meridians and base lines of the township survey system, frequently cross the lines of the precise level net, and the elevations at each crossing were based on the elevations of the precise bench marks as given by the general adjustment of 1923. That general adjustment has now, however, been superseded by the adjustment of 1928, and the precise level elevations have all been changed. This change has, in turn, made it necessary to alter all the secondary elevations. As the changes in the precise levels are not uniform, but vary considerably over the extensive areas in the West, the amount of change has to be computed separately for each individual secondary bench mark. The change is always positive, that is, the new elevation is always higher than the former. The amount varies from about 0·25 foot to 0·70 foot, the greatest changes being in the regions around Canora and to the northwest of Moose Jaw. In the two provinces, Saskatchewan and Alberta, about 220 circuits of secondary levelling, exclusive of the numerous smaller circuits around individual townships, have been involved in this readjustment. These circuits include 3,100 permanent bench marks, for all of which the new elevations have now been computed.

Field Operations

As in 1928, the field operations of the Levelling Division in the summer of 1929 were about equally divided between precise and secondary levelling. Work was carried on in five of the provinces—a precise levelling party operating in British Columbia, a secondary party in Quebec and one party of each kind in the province of Ontario. In addition to the four regular parties a special party was engaged in the establishment of fundamental bench marks in Manitoba and Saskatchewan.

Levelling in British Columbia

The first half of the season's work for this party lay in the northern interior of the province, the line of levels following the Cariboo road from Quesnel to Prince George and thereby connecting the levels which had been run on the Pacific Great Eastern railway from Squamish to Quesnel in 1927-28 with the previously established levels along the Canadian National railway through Prince George.

From this district the party proceeded to Vancouver island and started work at Victoria. Two lines were run, one following the Canadian National railway to Sidney and the other, the Esquimalt and Nanaimo railway to Nanaimo, all elevations being based on the reference bench mark of the Tidal and Current Survey of the Hydrographic Survey, Department of Marine, at Victoria, the elevation of which has been established by that Survey by means of automatic gauge records extending over a period of years.

In the course of the season's work two fundamental bench marks were constructed, one at Prince George and the other at Victoria.

Fundamental Bench Mark in Memorial Park, Assiniboia, Sask. The actual bench mark is a bronze tablet, three inches in diameter set in the top of the monument. On a bronze plate on one face of the monument is inscribed the elevation of the bench mark above mean sea level.

LEVELLING IN QUEBEC

One secondary levelling party operated wholly within this province and, in addition, the work of the Northern Ontario precise levelling party extended into the Rouyn district of Quebec for part of the season.

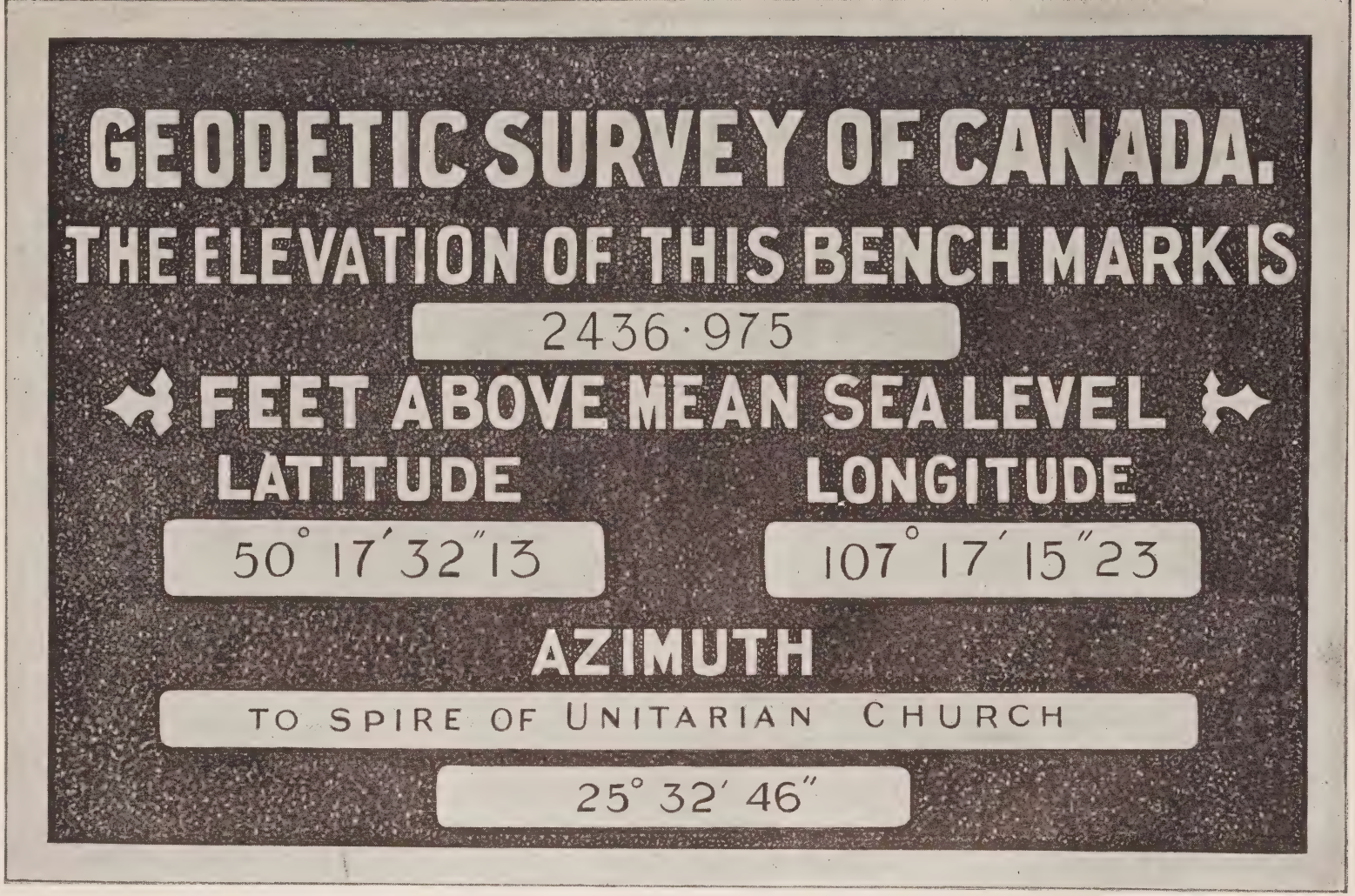
The secondary levelling party started from La Malbaie (Murray Bay) on the lower St. Lawrence, the terminus of a precise level line from Quebec city, and followed provincial highway No. 15 through St. Simeon, Doreil, L'Anse St. Jean, and Grande Baie to Port Alfred, where the levels were closed on the Quebec-Chicoutimi-Bagotville precise level line. The major portion of this highway was still under construction while the levels were being run, thereby causing difficult conditions in regard to transport especially after a very heavy rainfall in the early part of the season. The rough and hilly nature of the country also tended to slow up the work. In spite of these difficulties however the levels closed on the terminal bench mark with a discrepancy so small as to be regarded as highly satisfactory.

The second portion of the season's work, in contrast to the first, followed a surfaced highway. The levels started at St. Felicien, the terminus of a branch from the Quebec-Chicoutimi-Bagotville line above mentioned, and followed highway No. 15 around the north side of lake St. John to close at Ile Maligne at a precise bench mark on another branch from the same precise level line. As a result of this work a belt of Geodetic Survey levels completely encircles lake St. John intersecting such important tributaries as the Ashuapmuchuan, Mistassini, Peribonka and Metabetchouan, as well as the Little Discharge and Grand Discharge—the two outlets of lake St. John. According to regulations permanent bench marks have been established in convenient proximity to the crossings of all these rivers.

The regular field operations of the Quebec levelling party, as above outlined, were brought to a close about the end of August and the party was disbanded. A request was received later from the Beauharnois Power Corporation for a system of precise levelling control to be laid down in the territory crossed by its power canal. In conformity with the practice followed in several previous instances with commercial concerns and municipalities, whereby the Geodetic Survey loans the services of one of its engineers and the other party furnishes the assistants and pays all incidental expenses, the chief of the Quebec levelling party was assigned to this work and left Ottawa on October 15. Between five and six weeks was required to complete the field work, which included the whole route of the canal and adjacent territory between lake St. Francis and lake St. Louis, together with lines to the north shore of the St. Lawrence river at two points. Some forty or fifty permanent bench marks were established in the district as a result of the levelling, all elevations being based on the 1928 adjusted datum of the Geodetic Survey as furnished by the original precise level line passing through Valleyfield, P.Q.

LEVELLING IN ONTARIO

As mentioned earlier in this report, two parties, one on precise levelling and one on secondary levelling, were designated as Ontario parties. The first portion of the operations of the precise levelling party, however, lay mainly within the province of Quebec, starting at Swastika, Ont., and following the Nipissing Central railway easterly across the interprovincial boundary to Rouyn and Noranda, thence following the Canadian National railway northerly to finish at Taschereau, P.Q. The line closing satisfactorily on the old levels at Taschereau, the party proceeded to Cochrane, Ont., and completed the season's operations working northerly towards James bay along the recently constructed



Fundamental Bench Mark Plate, Monument Type, as shown attached to monument in illustration on page 25.

extension of the Temiskaming and Northern Ontario railway. Work was discontinued for the season at a point some 65 miles north of Cochrane, connection being made *en route* with bench marks of the Abitibi Electric Development Company at their Island Falls plant. A fundamental bench mark was constructed in Lee park, Cochrane.

The secondary levelling operations started at Deux Rivières, on the upper Ottawa river, where work had been discontinued the previous season and proceeded westerly to North Bay, following the Canadian Pacific railway as far as Rutherglen and from there, the Pembroke-North Bay highway. Two precise level points, namely Hagar on the North Bay-Sudbury line of the Canadian Pacific railway and Rutter on the Toronto-Sudbury line of the same railway, were then linked by a line of secondary levels along country roads through Noelville.

After completing this connection the party returned to Callander, at the junction of the Pembroke-North Bay and Toronto-North Bay highways, and ran a line of levels southerly along the latter to Powassan, thence in a general southwesterly direction through Nipissing, Commanda and Magnetawan to Parry Sound, and thence southeasterly, closing the season's operations at a point near the village of Rosseau. In the course of the season's levelling fundamental bench marks were constructed at North Bay and Parry Sound, these being tied in directly with precise level bench marks nearby.

LEVELLING IN MANITOBA AND SASKATCHEWAN

A special party consisting of an engineer and one assistant established fundamental bench marks in certain cities and towns of Manitoba and Saskatchewan, this being a continuation of the previous year's program in the prairies.*

Monuments—fourteen in all—were established at the following places in Manitoba: Brandon, La Rivière, Minnedosa, Napinka, and Portage la Prairie. In Saskatchewan they were established at Arcola, Assiniboia, Davidson, Estevan, Kerrobert, Kipling, Lanigan, Prince Albert, and Weyburn.

The actual construction, in accordance with previous practice, was carried out in each place by contract or by day labour employed locally. Additional standard bench marks were established in several of the places at which fundamentals were constructed, these for the most part being in public buildings of a permanent nature erected at dates subsequent to that of the original levelling.

SPECIAL WORK

At the end of 1928 a total of 67 fundamental bench marks had been established in various parts of the country. The elevations of these, along with all the other bench marks in the precise level system, having been determined by the general adjustment made in the year 1928, it was decided to adopt the practice of attaching plates to these monuments stating their elevation. Accordingly a bronze plate of rectangular shape, 7½ inches in length was designed, bearing the name of the Survey and the words: "The Elevation of this Bench Mark is.....feet above mean sea-level" The plate is attached by means of four anchorages to the most conspicuous side of the monument. Forty-five such plates were mounted during the season, thirty-two of these being in eastern, central and southwestern Ontario. The elevation of each fundamental, to the nearest thousandth of a foot, was stamped or engraved in the space provided before attaching the plate.

*A full description of the fundamental bench marks and the principles guiding their location will be found in the Annual Report of the Director for 1926.

It is felt that the plan of marking the elevations directly on the monuments will not only prove a great convenience to engineers desiring to base their work upon them, thereby promoting the use of the accurately determined mean sea-level datum, but will also tend to interest the general public in the activities of the Geodetic Survey and will thus lead to greater care in the preservation of all marks and monuments by the public. Due to the fact that the monuments are in nearly all cases situated in parks or public squares they are especially valuable in the latter respect.

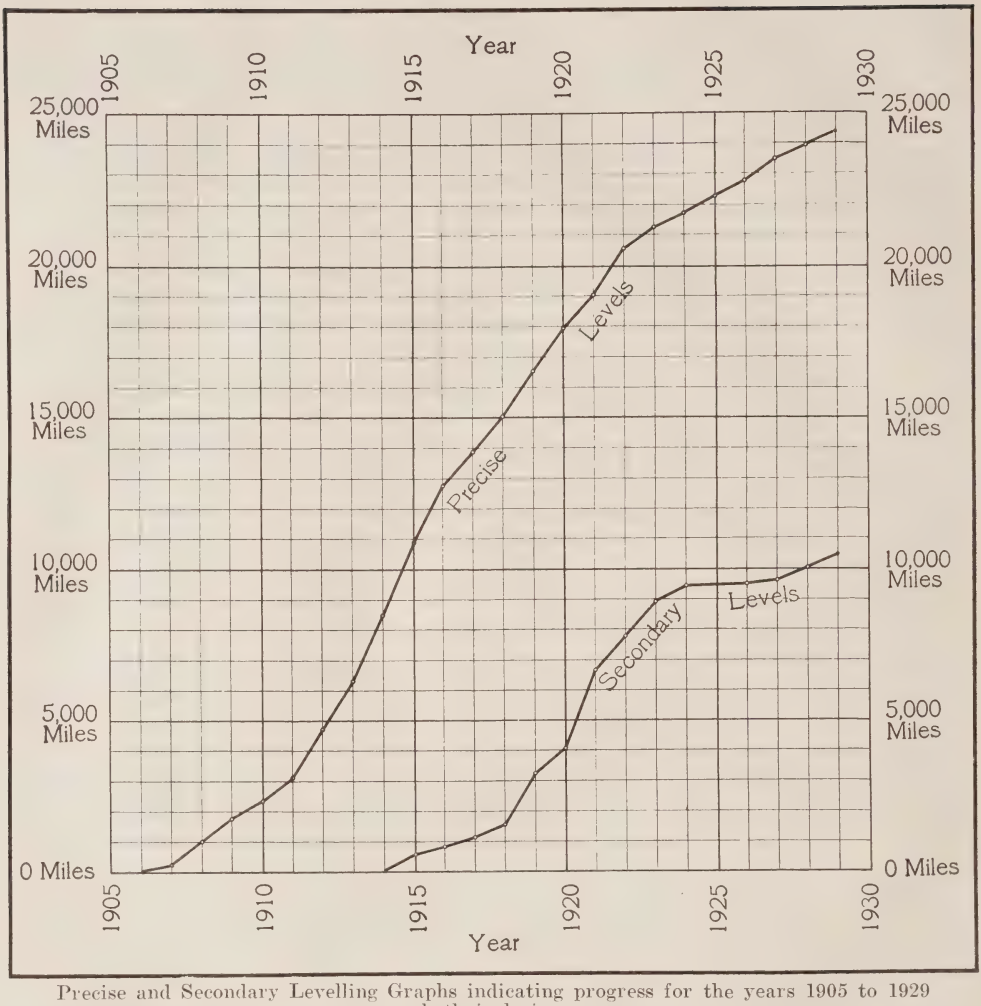
PRECISE AND SECONDARY LEVELLING RUN BY THE GEODETIC SURVEY IN 1929

The following is a detailed statement of the mileage of levelling run in 1929:—

Line	On Railway	Off Railway	Total
Precise Levelling—	miles	miles	miles
Quesnel to Prince George, B.C.	0·0	81·0	81·0
Victoria to Sidney, B.C.	16·2	1·0	17·2
Victoria to Nanaimo, B.C.	72·5	3·0	75·5
Swastika, Ont., to Taschereau, Que.	102·5	0·7	103·2
Cochrane, Ont., northerly	64·6	4·2	68·8
Special levelling north of Maniwaki, Que.	0·0	39·5	39·5
Beauharnois Power Canal	0·0	60·0	60·0
City of Chicoutimi, Que.	0·0	5·7	5·7
	255·8	195·1	450·9
Secondary Levelling—			
Deux Rivières to North Bay, Ont.	40·0	28·2	68·2
Hagar to Rutter, Ont.	0·0	40·3	40·3
Callander to Rosseau, Ont.	0·0	117·9	117·9
Murray Bay to Port Alfred, Que.	0·0	108·9	108·9
St. Félicien to Ile Maligne, Que.	0·0	89·6	89·6
	40·0	384·9	424·9

Summary by Provinces for 1929

——	Miles	Bench Marks
Precise Levelling—		
British Columbia	174	71
Saskatchewan	0	13
Manitoba	0	7
Ontario	102	62
Quebec	175	71
	451	224
Secondary Levelling—		
Ontario	226	87
Quebec	199	75
	425	162



Precise and Secondary Levelling Graphs indicating progress for the years 1905 to 1929 both inclusive.

The total mileage of precise and secondary levelling in each of the provinces at the end of the fiscal year is as follows:—

—	Precise Levelling			Secondary Levelling		
	Prior to 1929	1929	Total	Prior to 1929	1929	Total
Nova Scotia	729	.....	729	.....	.....	.....
New Brunswick	1,096	.....	1,096	.....	.....	.....
Quebec	3,184	175	3,359	169	199	368
Ontario	5,740	102	5,842	403	226	629
Manitoba	2,263	.....	2,263	368	.....	368
Saskatchewan	4,113	.....	4,113	5,098	.....	5,098
Alberta	2,866	.....	2,866	3,795	.....	3,795
British Columbia	3,279	174	3,453	.....	.....	.....
Yukon	458	.....	458	.....	.....	.....
Minnesota	89	.....	89	.....	.....	.....
Vermont	6	.....	6	.....	.....	.....
Total	23,823	451	24,274	9,833	425	10,258

The mileage of precise levelling along each of the railways is as follows:—

Railway	Miles	Railway	Miles
Canadian National	11,691	New York Central	55
Canadian Pacific	7,522	Père Marquette	55
Northern Alberta*	452	Maine Central	36
Temiskaming and Northern Ontario	385	Roberval and Saguenay	13
Kettle Valley	364	Napierville Junction	28
Pacific Great Eastern	357	British Columbia Electric	28
Algoma Central	319	Quebec Railway, Light and Power Co.	25
Great Northern	230	London and Port Stanley	24
Quebec Central	149	Alma and Jonquière	16
Dominion Atlantic	146	Maritime Coal, Railway and Power Co.	12
White Pass and Yukon	91	Michigan Central	3
Témiscouata	82	Highways and cross-country levels	2,042
Esquimalt and Nanaimo	72		
Nipissing Central	59		24,274

*Edmonton, Dunvegan and British Columbia railway and Alberta and Great Waterways railway.

PRECISE LEVELLING ADJUSTMENTS

Precise levelling field work of the season 1928 was introduced into adjustment No. 9. This gave up-to-date elevations for all junction points in the precise level net of Canada. From these elevations were obtained the elevations of all bench marks on lines contained in the net as well as on branch lines running therefrom. These are contained in publications of the Geodetic Survey of Canada and are available in convenient form for all engineers of federal and provincial government surveys, municipalities and corporations desiring such.

A short explanation of the orthometric correction and its application to level lines was prepareed, together with a table showing the magnitude of these corrections on the various types of lines.

A graph was also prepared illustrating the effects of the seven adjustments on the elevations of a selected number of points across the Dominion. These adjustments were made in such a way that each is a differential adjustment added to the preceding one. In the graph the elevations obtained from the first adjustment are represented by the zero line and the correction added by each of the other adjustments is seen in variations from this zero line. Adjustment No. 1 contained all precise level lines of topographic and geodetic surveys up to 1921 based on the Atlantic tidal stations, Halifax, Yarmouth, and Father Point. No. 2 added the Pacific tidal stations, Vancouver and Prince Rupert. No. 3 included conditions formed by breaking up the circuit Edmonton-Lacombe-Alix-Tofield-Edmonton by a line from Camrose to Wetaskiwin. No. 4 took new work of the season 1922, No. 5 the work of 1923, No. 7 that of 1924 and No. 9 that of later years, including a number of these conditions involving lake levels.

The above adjustment, together with the discussion of a number of interesting matters such as a precision of lines, functions of lines, weighting of lines, probable errors of loops, are dealt with in Publication No. 28, which is now in print and is being distributed.

During the year there have also been added, to the adjustments mentioned above, seven new conditions resulting from the inclusion of a number of lines of United States precise levelling along the eastern portion of the international boundary. The effects of these conditions have been tabulated to show the differences in elevation resulting from this inclusion. These differences range from a maximum of about 0·05 feet in bench marks along the international boundary between New Brunswick and the United States, and between Quebec and the United States, to practically zero throughout Western Canada.

GEODETIC RESEARCH

Two publications have been placed in the hands of the printer during the past year. One deals with the problem of how the observations of precise traverse and triangulation may be combined in one adjustment and the other explains the theory of the differential adjustment.

A problem which has been under consideration for some time is that of transferring geodetic data from one ellipsoid to another. This problem was discussed at the meeting of the International Geodetic and Geophysical Union at Madrid in 1924. The present use throughout the world of a plurality of ellipsoids defining the size and shape of the earth presents a difficulty in the transferring of geodetic results from one ellipsoid to another.

For the sake of uniformity the conference adopted the dimensions of the earth as given by the United States Coast and Geodetic Survey resulting from its investigations in isostasy and the deviation of the plumb line. The spheroid thus adopted was called the Hayford ellipsoid. Although the Hayford ellipsoid depends upon the data of astronomical deviations in the United States, it has not been and is not at present the ellipsoid actually used in the United States. In that country as well as in Canada and Mexico the Clarke spheroid of 1866 has been and is being used.

In addition to these ellipsoids there is also being used in Europe, the Bessel, and in Africa, the Clarke spheroid of 1880, slightly different from that given by Colonel Clarke in 1866. The use of various ellipsoids has created and is creating confusion as regards defining the latitudes and longitudes of points on the earth's surface.

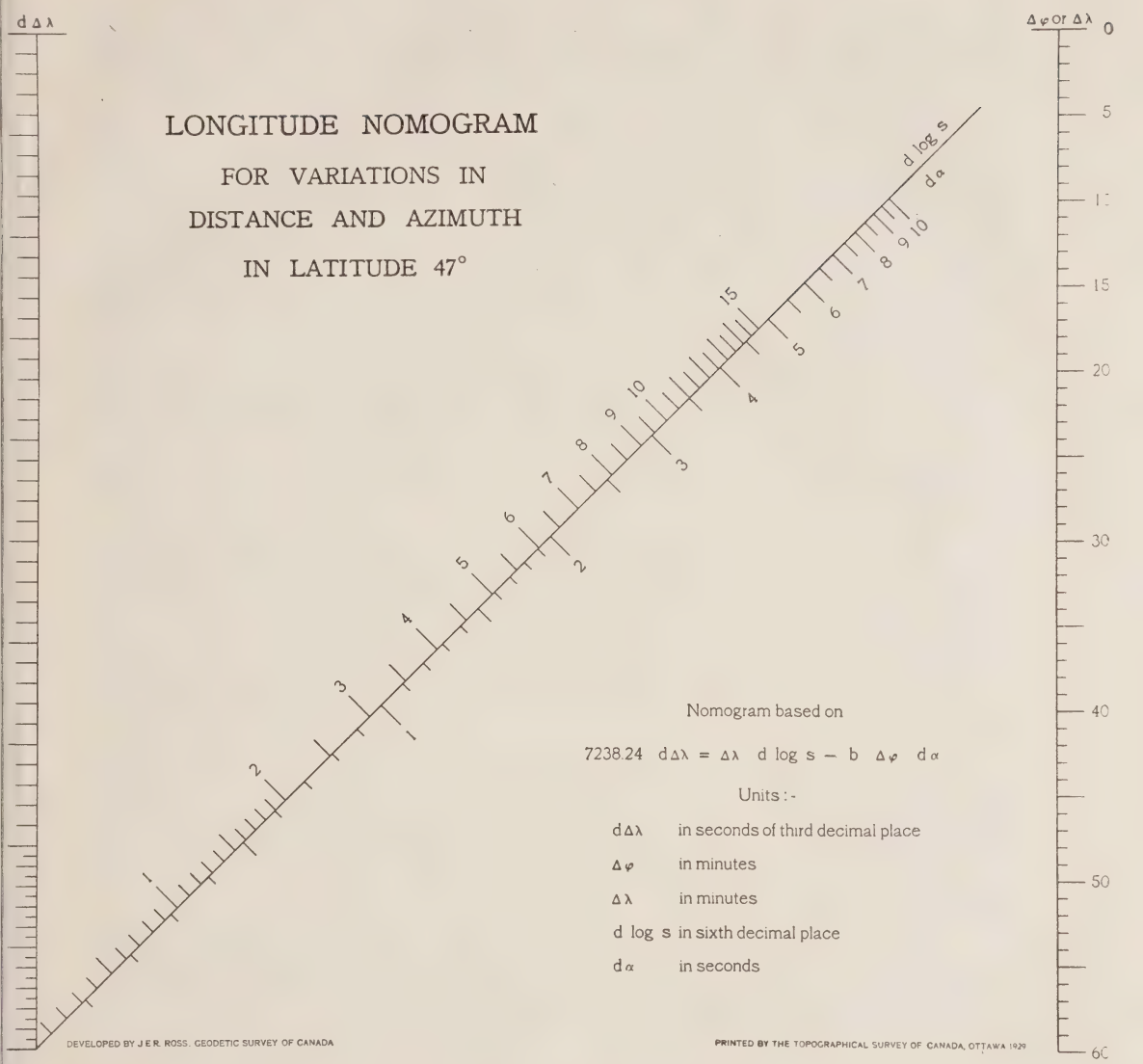
The problem of transferring geodetic results from one ellipsoid to another is one which must be solved for the sake of uniformity. While the solution of the problem is not by any means near completion, it is felt that the progress which has been made in this Survey is sufficient to inspire the hope that the solution is not far away.

TRIANGULATION ADJUSTMENTS

Early in 1926 the field work of the first order triangulation in Eastern Canada was completed to the stage where a connection was obtained between the work carried eastward from Montreal, P.Q., and that carried eastward in New Brunswick and Nova Scotia along the bay of Fundy.

The loop formed consists of 1,860 miles (2,995 km.), of which 1,300 miles (2,095 km.) is Canadian triangulation and the remaining 560 miles is part of the Oblique Arc of the United States Coast and Geodetic Survey. The Canadian section is in two parts. The northerly part was commenced in 1908 and was carried from United States stations near Montreal, in the province of Quebec, northeast down the St. Lawrence river and gulf to Anticosti island, then extended southward along the coast of New Brunswick to the head of the bay of Fundy. The southerly part was extended eastward from the eastern end of the United States Oblique Arc to meet the northerly part at the head of the bay of Fundy. The United States Oblique Arc proceeds southwest from the mouth of the bay of Fundy, and a spur from this arc proceeds northerly to Montreal. Included in the Canadian net are four base lines and six Laplace stations, besides two United States lines of fixed length and azimuth.

With the extension of the field work from year to year, the northerly part of the Canadian section of the loop was finally adjusted in four nets, thus giving a position for station Shepody, at the head of the bay of Fundy. The position of Shepody was also obtained from the southerly or Bay of Fundy triangulation. The differences of the co-ordinates of Shepody express the error in closure of the loop over the total mileage. The error of closure was $0''\cdot204$ in latitude and



Longitude Nomogram for Variations in Distance and Azimuth in Latitude 47°.

(Note—Longitude and Latitude Nomograms in Latitude 47° are available in printed form and may be had upon application to the Director of the Geodetic Survey, Department of the Interior, Ottawa.)

0″·750 in longitude; the values of the northerly section being south in latitude and west in longitude of the position as obtained through the Bay of Fundy triangulation. Expressed as a ratio of the total length of the loop, this closure amounts to 57 feet (17·4 metres) in 1,860 miles, or 1 part in 172,000.

As further work adjacent to and within the area would become necessary at a future date, it was decided to adjust the Canadian section of the loop to absorb the total error of closure and to use it as a main framework upon which subsequent work could be adjusted. The attachment of subsequent work up to date has been satisfactory. This procedure has permitted the entire triangulation of the Maritime Provinces to be adjusted and prepared for publication.

The published results will be held unchanged for an indefinite period, in fact, until such time as the triangulation has been extended over a much larger area and the resulting closures require a consideration of first order triangulation in toto.

The error of closure was distributed through a chain of triangles representative of the accuracy of the Canadian section of the triangulation. The angles used in this chain were the adjusted angles as derived from the net adjustments which, with one exception, were controlled by base lines and Laplace azimuths. The most probable values of the corrections to these angles, which would eliminate the total closure, were found and used to compute the co-ordinates of the junction points of the separate nets. Latitude and longitude equations were then added to the former adjustments to make each net fit the assigned value of its junction point.

The co-ordinates in each revision have to be re-calculated and this involves considerable labour. A study made to lighten this phase of the operation resulted in the development of a graphical method. The principle of this method is that the changes in the co-ordinates of the point at the far end of a line, due to a variation in the length and in the azimuth, can be readily obtained without decrease in accuracy.

The graphical method is outlined in Publication No. 35 of this Survey, in which copies of latitude and longitude nomograms suitable for first and second order triangulation appear with an example worked out and tested. The nomograms are in the form of Z charts, each chart containing two natural vertical scales and two semi-logarithmic diagonal scales. Each of the changes in the differences of latitude and longitude is obtained from the sum of two settings of the index line, one for the variation in distance and one for the variation in azimuth.

The correlation of the supplementary work within the principal nets of triangulation is being carried out in the various sections as they are prepared for publication. The results of this work are always sufficiently accurate for engineering purposes. On account of the ease with which any required surveys may be tied in to supplementary stations of the Geodetic Survey due to its convenient location to highways and coast lines, the usefulness of the Survey is greatly enhanced.

Numerous requests have been received from federal and provincial survey organizations for geodetic control data during the past year. It is worthy of mention that the number of requests for geodetic control on the part of corporations and private engineers is increasing rapidly.

LOCALITY OF FIELD OPERATIONS, FISCAL YEAR 1929-30

TRIANGULATION

Southern British Columbia.—Primary Triangulation—reconnaissance, angular measurements, station preparation.

Saskatchewan.—Primary Triangulation—reconnaissance, angular measurements, station preparation and tower building.

Northern Ontario.—Primary Triangulation—reconnaissance, angular measurements, station preparation, tower building. Precise traverse.

Northern Quebec.—Primary Triangulation—aerial reconnaissance, angular measurements, station preparation and tower building.

Gatineau Valley, Que.—Primary Triangulation—aerial reconnaissance, angular measurements, station preparation and tower building.

Eastern New Brunswick.—Primary Triangulation—angular measurements.

GEODETIC ASTRONOMY, ISOSTASY AND BASE LINES

Northern Ontario and Quebec.—Laplace stations.

Quebec and New Brunswick.—Isostasy investigation.

Manitoba-Ontario Boundary and Hudson Bay.—Astronomical positions.

Alberta and Saskatchewan.—Base line measurement.

LEVELLING

British Columbia.—Precise levelling.

Saskatchewan and Manitoba.—Construction of fundamental bench marks.

Ontario.—Precise and secondary levelling.

Quebec.—Secondary levelling.

PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

Publication No.

2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec, 10 cents.

3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239, 10 cents.

5—Field Instructions to Geodetic Engineers in Charge of Direction Measurement on Primary Triangulation, 10 cents.

Instructions to Lightkeepers; Use of Electric Signal Lamps being an Appendix (No. 4) to Publication No. 5, 10 cents.

7—Geodetic Position Evaluation, 10 cents.

8—Field Instructions for Precise Levelling, 10 cents.

10—Instructions for Building Triangulation Towers, 10 cents.

11—Geodesy, 50 cents.

12—Mathematical Statistics of the Geodetic Survey of London, Ont. (Distributed at London, Ont.)

14—Levelling, Co-ordination of Elevations of Bench Marks in the City of Calgary, Alberta, 10 cents.

15—Levelling. Bench Marks Established along Meridians, Base Lines and Township Outlines in Saskatchewan, 10 cents.

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18—Levelling. Precise Levelling in Quebec North of St. Lawrence River, 10 cents.

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PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA—*Concluded*

Publication No.

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30—Triangulation in New Brunswick and Nova Scotia, 50 cents.

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Report of the Operations of the Geodetic Survey of Canada, April, 1912, to March, 1922, prepared by the Director for the First General Assembly of the International Geodetic and Geophysical Union held at Rome, 1922. (Bound with the Reports of the Section of Geodesy of the International Geodetic and Geophysical Union, 1922), 10 cents.

Report of the Operations of the Geodetic Survey of Canada, April, 1922, to March, 1924, prepared by the Director for the Second General Assembly of the International Geodetic and Geophysical Union held at Madrid, 1924, 10 cents.

Report of the Operations of the Geodetic Survey of Canada, April, 1924, to December, 1926, prepared by the Director for the Third General Assembly of the International Geodetic and Geophysical Union held at Prague, 1927, 10 cents.

37—Geodetic Operations in Canada.—January 1, 1927, to December 31, 1929. Reports of the Section of Geodesy—The International Geodetic and Geophysical Union, Fourth General Conference, Stockholm, 1930, 10 cents.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918, 10 cents.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1922, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1923, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1924, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1925, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1926, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1927, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1928, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1929, 10 cents.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1930, 10 cents.

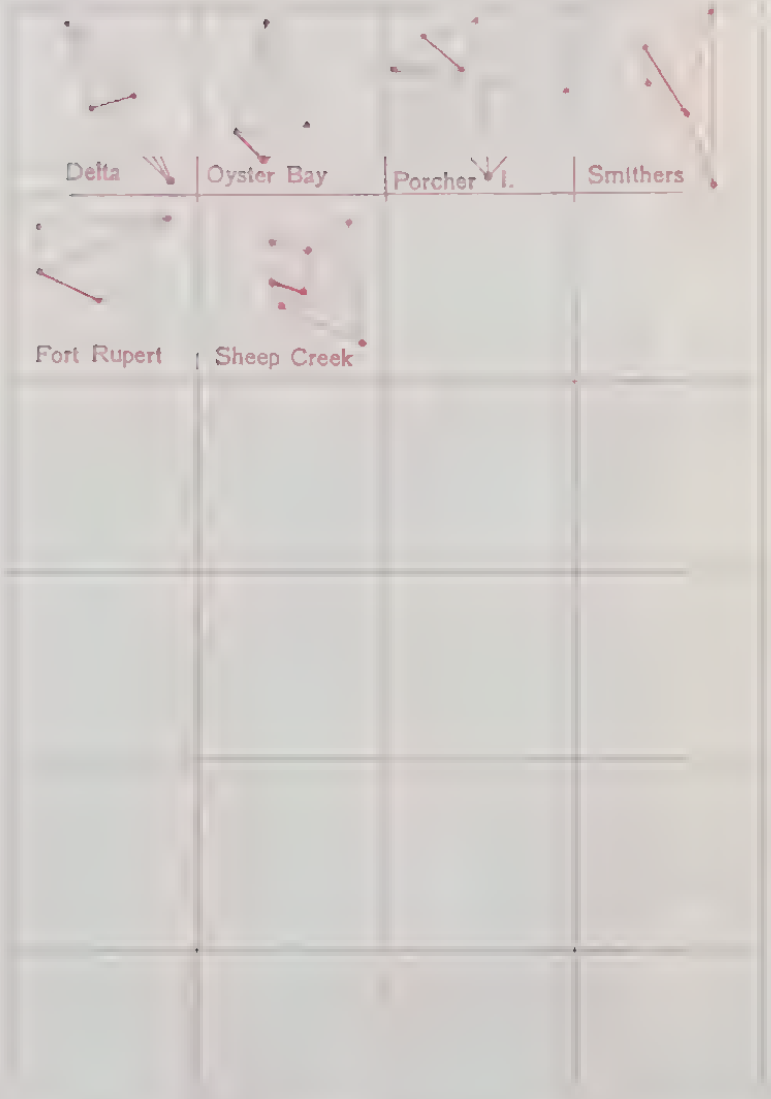
Where name and number are omitted, the publication is not available for distribution.

Copies of the above publications may be obtained by applying to the Director of the Geodetic Survey of Canada, Department of the Interior, Ottawa.

Reqn. 5344


GEODETIC SURVEY OF CANADA
PACIFIC AREA
FIRST ORDER
TRIANGULATION
Statute Miles
200
Triangulation Surveyed to Dec 31st. 1929.
Reconnaissance Triangulation shown by
Base Lines (name of Base). Laplace Stations
Precise Traverse

PACIFIC AREA
Triangulation
(over)

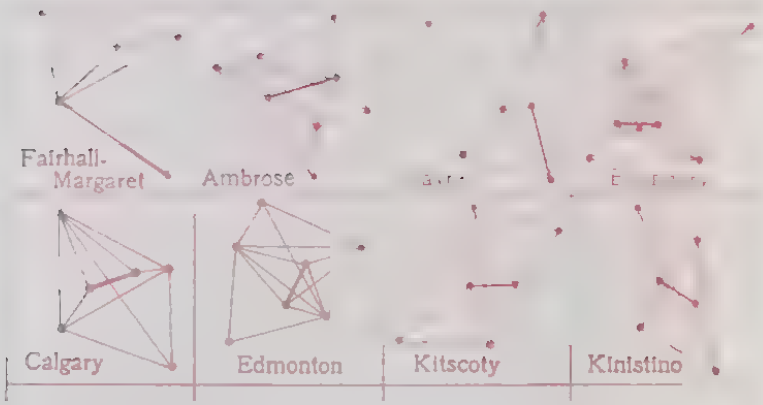


Base Line Expansion Nets


TRIANGULATION
PRAIRIE AREA

PRAIRIE AREA
Triangulation

(over)



Base Line Expansion Nets

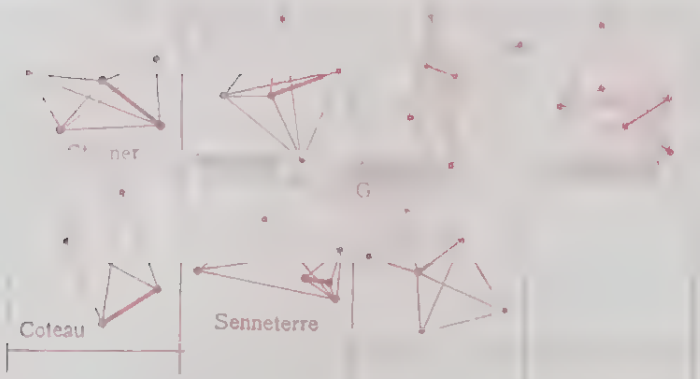
GEODETIC SURVEY OF CANADA

GREAT LAKES AREA

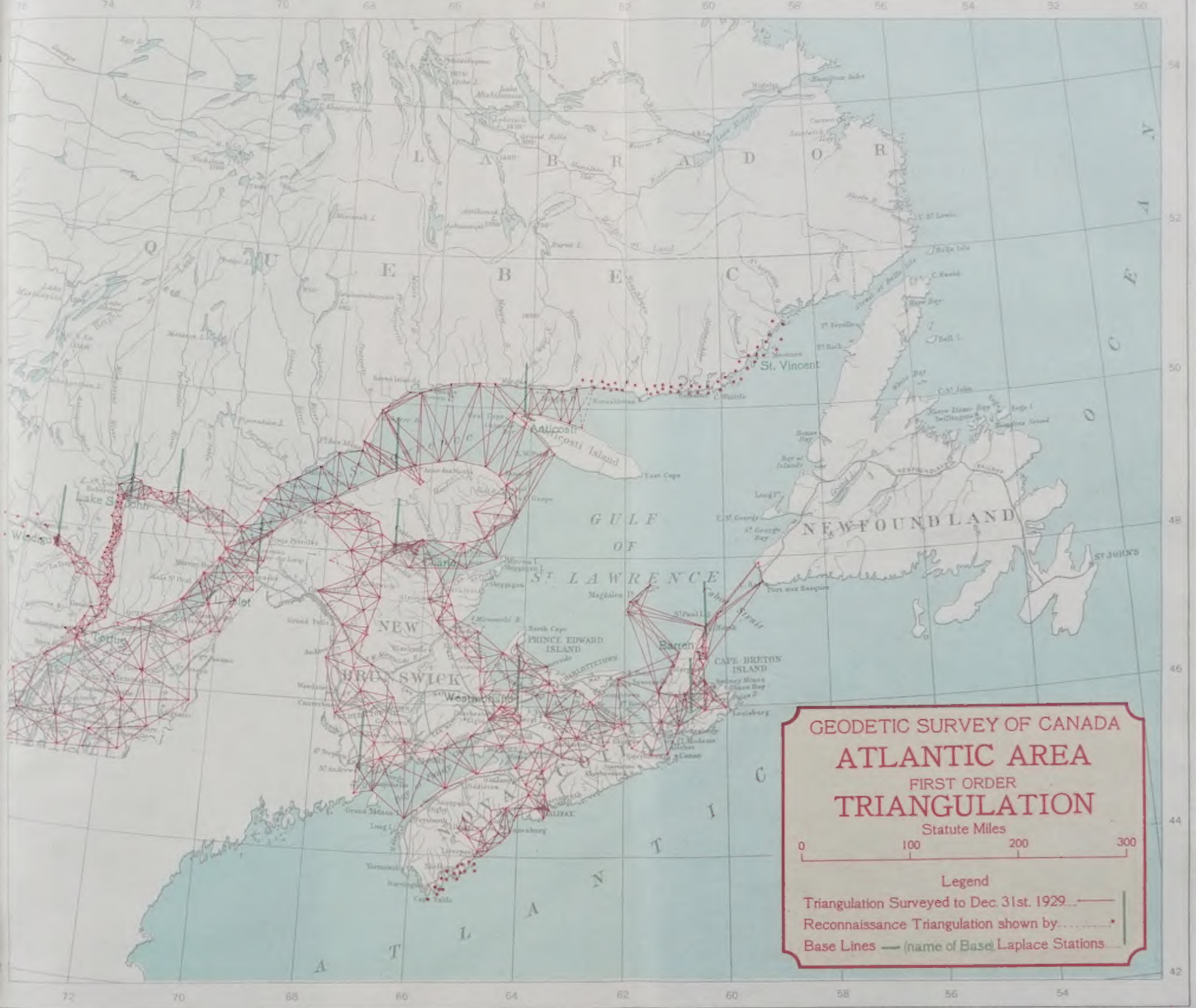
TRIANGULATION

GREAT LAKES AREA
Triangulation

(over)



Base Line Expansion Nets



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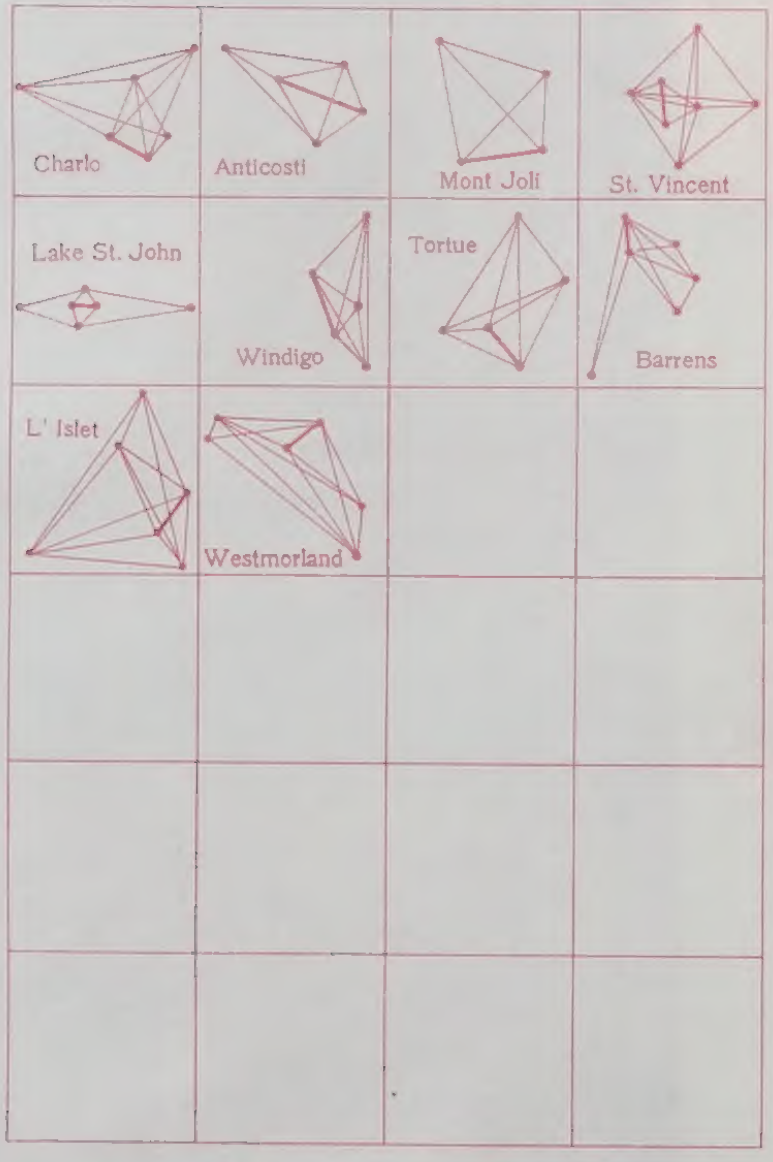
ATLANTIC AREA
Triangulation
(over)



Base Line Expansion Nets